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COMPUTER MAPPING as an aid in AIR POLLUTION STUDIES

VOLUME TWO: INDIVIDUAL REPORTS

REPORT I
CALIFORNIA STUDY

by

Paul Jack Dangermond

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16. Abstracts

A detailed report is presented of a study dealing with computer mapping and the air pollution problems of California. The study is divided into three sections on; Los Angeles County, San Bernardino County, and the State of California. Each section presents information on monitoring networks and discussion of the maps involved.

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COMPUTER MAPPING

as an aid in

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PREFACE

From July 1, 1968 through December 31, 1969, the Laboratory for Computer Graphics and Spatial Analysis conducted a demonstration of several conceptual, methodological, and technical approaches to problems in the field of air pollution, employing computer-produced maps and allied displays. This work was done under a grant (No. 68A-2405D) from the Division of Control Agency Development, National Air Pollution Control Administration (NAPCA), Public Health Service, U. S. Department of Health, Education, and Welfare.

The results of this study, taken in its entirety, should make an important contribution to the work of Federal, state, and local air pollution agencies, especially in their efforts to determine the best control strategies for use in air quality control regions. The computer is an ideal tool for relating and combining sets of data, and for considering alternatives. For instance, graphic displays can contribute significantly to the evaluation of both short-term and long-term control strategies.

In demonstrating "the use of computer graphics as a means for more clearly portraying data related to the sources, distribution, and community effects of air pollution," the primary emphasis was on case studies for specific areas. The secondary emphasis, to support and complement the case studies, included:

(a) "the development of instructional manuals covering the procedures required for the preparation and interpretation of computer maps of various kinds, as related to air pollution,"

(b) "the use of certain newly developed techniques for describing, analyzing, and portraying quantitative surfaces and movements relative to such surfaces, as related to air pollution," and

(c) "an appraisal of alternative equipment, techniques, and computer programs presently or potentially available for the production of computer graphic displays pertinent to air pollution."

The case study regions were selected in consultation with NAPCA. Considerations included:

(a) sufficient air quality, emission, and related socio-economic and meteorological data--spatially distributed over the region--to enhance the likelihood of adequately demonstrating the mapping techniques;

(b) representative problems in data handling and mapping so that the techniques demonstrated would have applicability to as many other areas as possible;

(c) special problems in data handling and mapping so that as many techniques as possible could be adapted, developed, and tested;

(d) areas of which NAPCA and the individual investigators had special knowledge and could therefore utilize relevant research to enhance the study;

(e) areas where an immediate interest in mapping had been expressed for on-going Federal, state, and local air pollution activities.

Other research was undertaken to support and complement the case studies, and, in particular, to provide:

(a) the widest possible distribution of the mapping programs and accompanying explanation of the techniques through

i) copies of the Laboratory's SYMAP Computer mapping program,
ii) an introductory correspondence course in the SYMAP program,
iii) general program description and supplementary explanation for the existing user-manuals;

(b) a general review of present and potential hardware, output devices, and programs applicable to computer graphic displays of air pollution and related data;

(c) means for predicting, projecting, and correlating air pollution and related data, utilizing the latest

knowledge in planning, geography, and spatial analysis in general;

(d) dissemination of information on approaches and techniques to Federal, state, and local air pollution agencies, especially for use in the air quality control regions.

The final report is divided into two parts: Volume One: Summary, and Volume Two: Individual Reports--the detailed reports on the case study areas and the technical reports related to other research undertaken. The pertinent graphic displays are included with the appropriate individual report and a complete set is provided with the Summary Volume.

Introductory sections describing the air pollution and related data used are provided in the major case study reports for St. Louis and Kansas City; these should be referred to by anyone unfamiliar with the types of data and problems existing in this field. Detailed discussions of special data handling and mapping techniques are presented either as appendices to case study reports, or in separate technical reports.

The Summary Volume includes a discussion of all the areas of research undertaken and contains the complete table of contents for the reports of Volume Two. This should provide a useful reference of the special problems and technical discussions of one report which may be of interest to the reader of another detailed report.

The California Study is presented here as Report I of Volume Two. It is divided into three sections on Los Angeles County, San Bernardino County, and the State of California. An Appendix of computer graphics produced is included.

The data used in this study was provided by various persons in the criteria and standards development program of NAPCA.

The study was under the direction of Paul Jack Dangermond. The report was prepared principally by the investigator.

John C. Goodrich. Editor
Cambridge, Massachusetts
April, 1970

REPORT I
CALIFORNIA STUDY

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1. LOS ANGELES COUNTY

The Los Angeles County study used data from an eleven-year investigation of carbon monoxide concentrations in and around Los Angeles County in California. This is among the most comprehensive set of air pollution data available, particularly for examining changes in air quality over time.[1] Most of the mapping was done using the calculated annual maximum carbon monoxide concentrations from 1956 thru 1967. Other pollution data used included the geometric mean, measured maxima, certain percentiles and an eleven year time series of the actual maximum values for each year.

Los Angeles County is divided into three sub-regions which are relevant to this study: inland and coastal valleys, mountains, and deserts. Because of the near unique inversion situations which occur the pollutants are often kept from dispersing out of the valley by the mountain range. Thus, the northern desert areas remain relatively free of pollution because they have little intrusion from the urbanized south and few intrinsic sources of pollution.

The major task of this study was to adequately represent the influence of the mountain range in inhibiting the flow of pollutants from the valley to the desert.

1.1. MONITORING NETWORK

Unlike the data available for the San Bernardino County Study, no pollution readings were taken for either the mountain or desert areas of Los Angeles County. Measurements

were used from 30 monitoring stations; 22 were located within the coastal valley of the County and the remaining 8 were located in adjoining counties to the east and west. This network of stations within the county and the three sub-regions are shown below.

When there are data point locations and values for only one part of a study area, the SYMAP interpolation algorithm will extrapolate values into other areas where the pollution concentrations are not known and often produce a display that is quite inaccurate. (2)

This is precisely what happened when a map was produced for the maximum carbon monoxide concentrations (calculated using 8-hour values for 1956 thru 1967) for

Los Angeles County using only the data points in the southern part of the area. The map is shown on the right in Figure I-1. The surface is reasonable in the southern part of the study area, but erroneous extrapolation of values takes place in the north.

To correct this situation several techniques were tried to simulate the "barrier" of the mountain range. The first technique assumed that the average height of the inversion layer could correspond to a given elevation of topography. Further assuming that this height is 3000 feet, one can say that the dispersion of pollution over the mountains is blocked along a contour elevation of 3000 feet. To represent this phenomenon, background or false values of 0.0 for pollution readings in the mountains were introduced. This is not entirely unreasonable since above the assumed inversion layer the pollution concentrations are extremely low relative to the rest of the study area.

Instead of placing a large string of data points at elevation 3000 feet, 8 mountain peaks above 5000 foot elevation were assigned pollution readings of 0.0 parts per million (ppm) concentration. It was hoped that interpolation using these points combined with the given monitoring stations in the valleys would cause a gentle and realistic decline in the surface of concentrations down to the background values at the actual inversion elevation. The resulting map is shown on the right in Figure I-2.

1.2. BARRIERS TO INTERPOLATION

These background values at 5000 feet elevation proved quite useful in approximating the expected levels of pollution.

However, to improve upon this generalized solution a second technique was examined. The SYMAP program can take into account obstacles which might inhibit or prohibit interpolation of values to any given point. The user specifies "barriers" which are used by the program in conjunction with the interpolation procedure.(3)

The final procedure used for making the Los Angeles County maps was a combination of permeable and impermeable barriers and the assumed background values in the mountains.

1.2.1. Barriers in the SYMAP program

In the SYMAP program if we wish to prevent or inhibit interpolation from one area to another-across some line dividing the areas--we place a "barrier" to the normal interpolation along the dividing line. The barrier acts to make data points on the other side appear to be further away than they actually are.

A barrier as used in SYMAP may be either "permeable" or "impermeable". Permeable barriers restrict interpolation across the barrier, but do not stop it. Impermeable barriers allow no interpolation across the barrier. In general, permeable barriers may be thought of as hurdles whose height above any point is the strength of the barrier at the point. Interpolation across the barrier would be affected by the added distance in jumping the hurdle. Impermeable barriers would be insurmountable hurdles.

Of the two, impermeable barriers are the easier to understand. To be used correctly, an impermeable barrier must divide the study area into completely separate regions. "Across" the barrier has a literal mathematical meaning: if the imaginary line from a control location to a data point crosses the barrier an odd number of times, then that point is across the barrier from the control location. If the line crosses the barrier an even number of times, then the barrier has no effect whatsoever on the interpolation from the data point to the character location under consideration.

The most common type of impermeable barrier is the dividing line barrier. A dividing line barrier begins at the map border and terminates at the map border, although it may change direction in between. It completely divides the study area. For example, if we wanted to separate the northern desert from the southern valley we would place an impermeable barrier from the left border to the right border along the mountain range.

Permeable barriers may be used to represent the inhibiting influence of bays, harbors, lakes, or other obstacles such as the mountain range in the Los Angeles case. Points across the mountain, or on the opposite sides of a pass, may still be thought to bear a relationship to each other, but the relationship would depend more on the distance through the pass. In the case of permeable dividing line barriers, the units (for barrier strength) are the same units in which data point locations are expressed. With this type of barrier the strength should generally be no greater than the average spacing between data points.

The great advantage of a permeable barrier is that we may vary the strength along the barrier. For "protruding barriers", this is an especially advantageous property For the Los Angeles mountain ranges there is a significant mountain pass which can be thought of as warranting a 'break' in the barrier. Therefore a barrier would protrude out from each map border to the location in the mountain range where the pass occurs. An impermeable barrier is not appropriate because pollution can disperse through the pass to the other side.

In all cases the barriers are determined by straight line segments connecting vertices. Each vertex of these barriers will have a different strength, starting with a strength of 0 at the mountain pass. In general the strength at the second vertex should be twice the length of the segment from the first to the second vertex, and so on for all the vertices. The strength at the final vertex on the map border will be roughly twice the total length of the barrier, in source units.

The strength of zero at one end of the barrier means it has no effect at that point. The other strengths approximate the effect of having to double around the barrier to avoid crossing it. In other words the strength at each vertex of a protruding barrier is twice the distance from the first vertex. This rule of thumb for determining strengths may not be appropriate for approximating the dispersion of pollutants through the mountain pass.

1.2.2. Use of Barriers with Mountain Areas

Both impermeable and permeable barriers were tried for Los Angeles County. First of all impermeable

barriers were placed at an elevation of 3500 feet. This resulted in quite an accurate map, with the exception of the region around the Santa Monica mountains. (See the left hand map in Figure I-2) The topography in this sub-region is quite varied, with many valleys at elevations less than 3500 feet which protrude into the mountain range.

A single impermeable barrier was used in the right hand map in Figure I-3, here the mountain pass was approximated by the location of the barrier. There was an erroneous influx around the eastern edge of the barrier, resulting from data points in adjoining counties. When two full strength (impermeable) barriers were used with an opening for the mountain pass, erroneous values were found in the northeastern part of the county as a result of interpolation through the opening. (See the left hand map in Figure I-4).

None of these solutions was adequate. To overcome the erroneous values for the Santa Monica mountains a half-strength permeable barrier was used in the west, with a full strength (impermeable) barrier on the east (see the left hand map in Figure I-3). Finally, two variable strength barriers were used to directly model the dispersion through the mountain pass (right hand map of Figure I-4).

The final solution used two variable strength protruding permeable barriers, in combination with background values on various mountain peaks. This is shown in the left hand map of Figure I-1. The number of background points used was a variable in the maps discussed

above and this influenced the results. The following table summarizes the barriers and data points used for each map including the background data points.

		Data Points		Barriers	
Figure	County	Adjoining	Background	Left	Right
I-1a	22	8	9	Variable	Variable
I-1b	22	8	0	-	-
I-2a	22	8	5	Full	Full
I-2b	22	8	8	-	-
I-3a	22	8	8	Half	Full
I-3b	22	8	1	- Full	-
I-4a	22	8	1	Full	Full
I-4b	22	8	3	Variable	Variable

The values for all background points were 0.0 except for Figure I-3b. Here a single full strength barrier was used; therefore, the only value used for interpolation in the upper part of the study area was this background point--a value of 5.0 ppm was used as a threshold. In all other cases some interpolation took place through the mountain pass.

1.3. DISCUSSION OF THE MAPS

Various maps were produced for Los Angeles County at the request of NAPCA.[4] The first set of maps shows the measured maxima carbon monoxide concentrations (calculated using eight hour values) for the years

1958 -- Figure 5b,
1959 -- Figure 6a,
1960 -- Figure 6b,

1961 -- Figure 7a, and

1962 -- Figure 7b.

Figure 5a shows the measured maxima for the entire time period 1956 thru 1967. For each of these maps there were 39 possible data point locations: 22 in Los Angeles County, 8 in adjoining counties, and 9 background points. However, for many of the years data were missing at one or more locations which greatly influences the maps produced. The missing data points are summarized below.

Figure	Year	County points missing	County points actual	Adjoining points missing	Adjoining points actual	background points
I-5a	1956-1967	11	11	8	0	9
I-5b	1958	13	9	8	0	9
I-6a	1959	16	6	8	0	9
I-6b	1960	15	7	8	0	9
I-7a	1961	11	11	8	0	9
I-7b	1962	0	22	0	8	9
I-8a	Geometric	0	22	0	8	9
I-8b	Percentile	0	22	0	8	9

If one quickly examines each of the maps of this time series a definite pattern of carbon monoxide concentrations emerges. The major centers of concentrations are in Watts and the San Fernando Valley. This pattern is further evidenced in the map for the 0.1 ppm percentile (Figure I-8b-- percent of the time concentration exceeds 0.1 ppm).

Figure I-8a shows the geometric mean of the maxima values for 1956 thru 1967. When this map is compared to the measured maxima (Figure I-5a) it is apparent that the areas which have the extreme maximums are also the same areas having overall higher average concentrations.

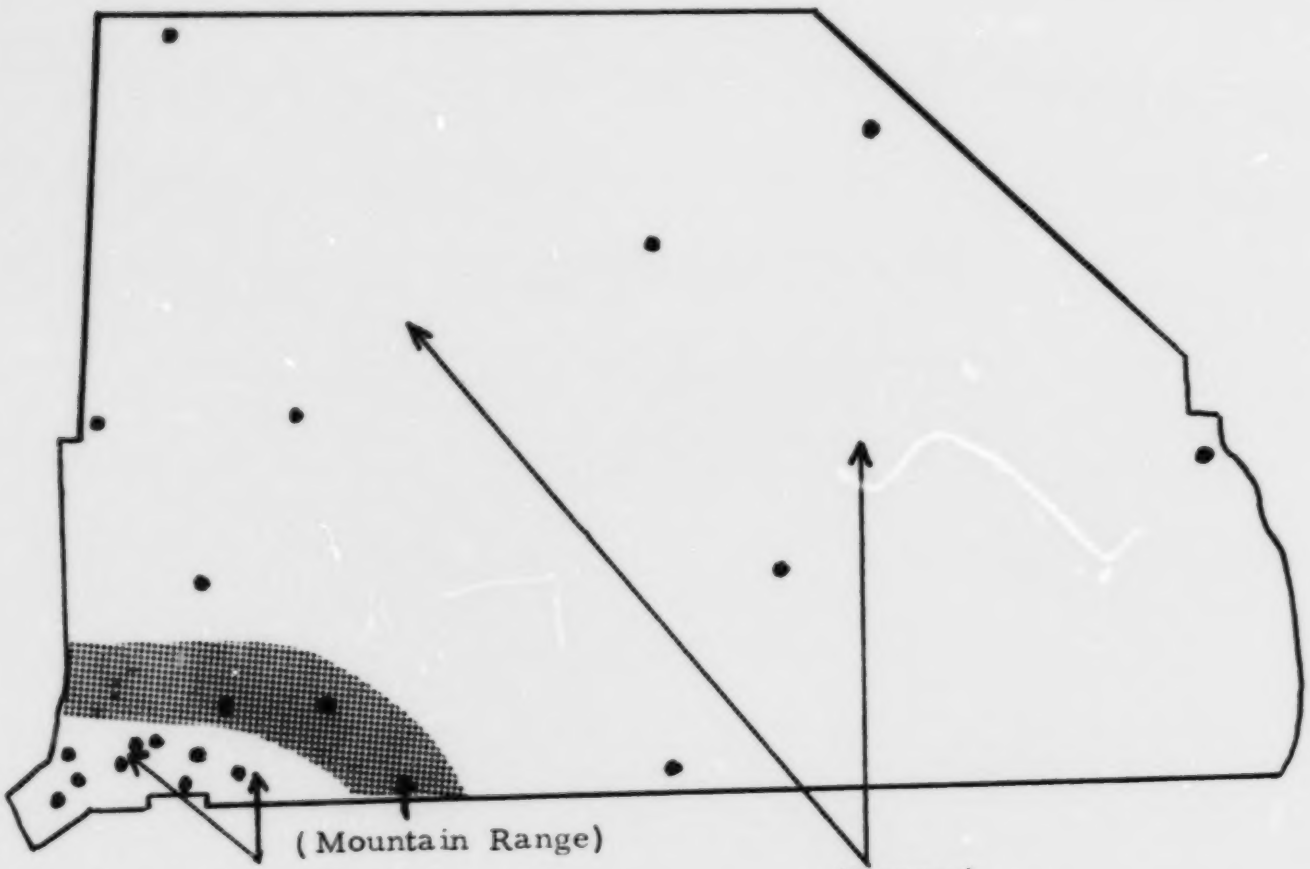
2. SAN BERNARDINO COUNTY

The second portion of the California study involved the mapping of values of total annual suspended dust concentration for San Bernardino County. This demonstration of the computer mapping techniques of the SYMAP program was unique in the availability of data point locations spaced adequately over the study area. The air quality data used in the study were measured by the San Bernardino County Air Pollution Control District with the help of a U.S. Public Health Service grant; the goal of this grant was the development of criteria to be used by local agencies in the formulation of regulations for suspended dust particulates.

2.1. DISTRIBUTION OF MONITORING STATIONS

The data used in this study were of particular interest in computer mapping because of (1) the spatial distribution of monitoring stations, and (2) the diversity of demographic and natural geographic regions where measurements were taken. The locations of the monitoring stations were selected so that each main type of landscape form and each category of population density was represented by a station. This gave a generally even distribution of stations; in addition, stations were located at the periphery of the County to measure the pollution intruding from outside the region.

The following map shows the distribution of the twenty monitoring stations used in the study.



There are three natural regions, as in the Los Angeles study: the inland urbanized valley, the mountain ranges, and the desert. The urbanized area in the southwest portion of the County has nine of the data points; this region is subject to the most variability in activities and pollution sources and thus warranted the greatest number of monitoring stations per unit area. On the other hand, the mountain areas have only two data points since there is less variability.

Finally, the desert areas have nine data points spread evenly over the County; five of these points measure intrusion at the County boundary.

The existence of these mountain and desert data points is in direct contrast to the Los Angeles County data. With actual 'background values' measured on the mountains and in the desert, 'dummy' mountain data points and barriers to interpolation were not necessary. This distribution of data points is particularly useful for contour mapping using a computer program such as SYMAP: the interpolation algorithm in the program is able to give a much more accurate representation of the actual surface of air quality in cases such as this. Without a good geographic distribution of data points, the SYMAP program will extrapolate values over great distances, often resulting in maps that can be misleading.(5)

Such a sampling network can also provide valuable insight into the relative levels of suspended dust concentration resulting from:

(1) man-made sources,

(2) natural sources, such as Death Valley in the northwest corner of the County, and

(3) intrusion from surrounding areas. such as Los Angeles County to the west.

2.2. DISCUSSION OF THE MAPS

The total annual suspended dust concentration for 1966, based on the geometric mean of the samples taken at each of 20 stations, was mapped and is shown in Figures I-9 and I-10[6]. The highest concentrations occur in three areas, each resulting from a different type of source:

(1) the southwest corner, resulting from man-made sources, particularly the steel mill in Fontane,

(2) the valley just north of the mountain range, resulting from natural sources and a flow of pollutants through the mountain pass from the southwest corner of the County, and

(3) the northwest corner, resulting from natural sources and intrusion from Death Valley.

The center map in Figure I-10 shows the geometric mean of samples taken at 18 stations in 1967 for total annual suspended dust concentrations. Since the value range and symbolism are the same as for 1966, the two maps are directly comparable. However, it is very significant that the two mountain area stations were not used in 1967, therefore, interpolation takes place directly from the southwest corner across the mountains to the desert valley to the north. In 1967, the highest readings were found in the desert region and not in the urbanized southwest corner of the County. These high readings could have been caused by an increase in either (1) natural background particulate matter due to a high incidence of dust storms, or (2) man-made particulate matter in certain towns. [7]

The righthand map in Figure I-10 shows the absolute increase or decrease in total annual suspended dust concentration from 1966 to 1967. Because both increases and decreases are shown on the same map, it is difficult to tell where the areas of least change occur; the symbolism has gradations from light, for greatest decrease, to dark for greatest increase. Separate maps for increase and decrease would be much easier to read.(8)

From this map we can see that the greatest increase in air pollution was in the desert region where the high readings were found for 1967. It is not possible to determine whether this increase is due to changes in man-made sources, natural background, or both. Another very large increase occured at the steel mill in Fontane, but this increase did not show up as strongly because of the close proximity of other monitoring stations, with either very low increases or actual decreases. This would seem to indicate that the dispersion of the pollution from the steel mill is not significantly increasing over the area as a whole, although the emissions of particulate matter are locally increasing. This is certainly a function of the scale of the map, and the placement of the monitoring stations.

Figure I-11 shows the geometric mean of the total suspended dust concentrations for the Spring, Summer, and Fall seasons in 1966. These were mapped with the same value range intervals and symbolism as the annual maps for 1966 and 1967; therefore, the maps are directly comparable. For all three seasons data were available at the 20 monitoring stations, including the two mountain area locations.

The surfaces for Spring and/Fall are surprisingly similar, with slightly higher levels of dust concentration occuring in the Fall season. In the Summer the southwest corner exhibited much higher readings, but the portion of the County exhibiting high readings was less. This would seem to indicate greater sources of man-made pollution in the Summer, but less natural background or intruding pollution.

3. CALIFORNIA

California is unique in regard to air pollution because it has had an air pollution control agency for such a relatively long period of time: the Bureau of Air Sanitation. In 1959 the State Department of Public Health was directed by the legislature to set the first comprehensive set of air quality standards in the nation.

This study was concerned with an examination of air quality in relation to these standards and to suggested new standards set forth at a conference in 1968. A nine month time-series of oxidant concentration as distributed across the state of California was mapped and a single month examined on a geographical basis to see how the oxidant standard had been violated.

3.1. LOCATION OF DATA POINTS

The mapping problems for such a large region were much the same as those encountered in several of the other air pollution studies, most notably Los Angeles County and Kansas City.[9] Because of the large variation across the state, in geography and landscape type as well as in settlement patterns and their resultant pollutant emissions, it is necessary to have a large number of monitoring stations to adequately represent all of the sub-regions that exist. Unfortunately, such an adequate representation is unavailable in California as it is in most states.

3.1.1. Monitoring Network

The placement of monitoring stations on a regional or state scale usually results in a clustering of stations in locations where the pollution concentration is most severe. Conversely, in areas where the pollution concentration is low, there are often no measurement stations at all. This discrepancy is difficult to deal with for mapping purposes because simple interpolation between the data points (monitoring stations) results in an unrealistic display of the spatial distribution of the pollution.[10]

The location of monitoring stations for oxidant in California can be seen in the right-hand map in Figure I-12. There are a total of 51 stations, as shown by the numbers 0 thru 9 and the letter "M". However, whenever an "M" occurs, this is an indication that data was missing or unrecorded for that time period (the month of January 1968 for this map). In this case valid measurements used for mapping were available at only 34 of the 51 stations.

3.1.2. Use of Mountain Range Barriers

The number and location of data points are not the only difficulties with the monitoring network. The significant changes in topography--particularly the mountain ranges which inhibit the normal flow of pollution--need to be taken into account. In the California case two alternative techniques were used to solve this problem. The first technique was to use false or 'background' values; the second technique was to use barriers.

Background points of zero value were placed on all mountain peaks above six thousand foot elevation. It was assumed that these mountain peaks were virtually free of any pollution and that some reasonable approximation of pollution levels would be made by interpolating from the peaks down to the monitoring stations at lower elevations.

In the second technique barriers were carefully placed along presumed "thresholds" of air pollution. These were mountain ranges that potentially blocked a breakup of an inversion in situations similar to that found in the Los Angeles County study. For the maps shown in Figures I-12 thru I-14 barriers at the 3500 foot elevation were used throughout the state.

In retrospect, although much of the mapping for this study was done using barriers, the background values technique would probably give a truer picture of air quality in a situation with as much geographic variation as California. Barriers have some serious limitations[11]; it is also difficult to determine what combination of barriers is optimum, and an extensive trial and error procedure may be necessary for this purpose.

The choice of barriers over background values is a decision involving the scale of the project. For the Los Angeles County study barriers were a good solution; at the State scale the complexity of the geography is such that the barriers technique produces many problems and the use of background values is probably a better solution. Some combination of the two techniques may yield the best results.

3.2. DISCUSSION OF THE MAPS

3.2.1. Maps of Oxidant by Month

The nine maps in Figures I-12 thru I-14 are a time sequence for monthly averages from November of 1967 thru July of 1968. The values are the maximum hourly averages for oxidant. The same isopleths and symbolism are used for each map: they use equal intervals of 0.05 ppm. The symbolism "H" occurs for areas where a level of 0.5 ppm was exceeded.

Oxidant is believed to be a synergistic pollutant related mainly to automobile exhaust emissions. We would, therefore, expect levels to vary according to automobile usage and the climatology for each month. Automobile usage is higher in the summer months than in the winter: the ventilation is also poorest during the summer. Examination of the time series in Figures I-12 thru I-14 shows that the lowest levels occured in December and the highest in July, on the average.

3.2.2. Comparison with Oxidant Standard

The center map in Figure I-13 demonstrates a technique for delineating areas which exceed a standard during a given period of time. The data used were the daily maximum hourly average concentrations of oxidant measured in ppm for the month of March, 1968.

The suggested oxidant standards as presented at the Tenth Methods Conference in San Francisco in November

1968 were used. They read as follows: "The standard will be exceeded for oxidant of more than 0.1 ppm on seven or more days in any three months period or on three or more consecutive days." This standard is based on various studies which correlate this level of oxidant with pulmonary function, eye irritation, and athletic performance.

The map in Figure I-13 shows the areas that exceeded this standard for the month of March, 1968. The dark areas represent areas where the concentration of oxidant was greater than 0.1 ppm for three consecutive days, or seven days over a three-month period from February through April. The locations of severe concentration are represented by the symbol "H". This technique of graphically showing areas where standards have been exceeded can be used with either a single pollutant or several pollutants in combination.[12] It can be very useful to a control agency, particularly when a time series of maps is produced.

REFERENCES

(1) The data had been analyzed and manipulated by the U.S. Public Health Service using various mathematical models most notably a model developed by Ralph I. Larson. This model uses data describing pollution concentration, frequency of pollution, and averaging times to produce the calculated annual maximum carbon monoxide concentrations in parts per million. The Larson model is discussed in Volume Two, Report D, Kansas City Region Study.

(2) The SYMAP interpolation algorithm is discussed in volume Two, Report L; the terms interpolation (determination of a value at any location on the surface, based on the data points) and extrapolation (determination of a value in an area relatively far removed from data points, such as the periphery) are often confused. The problem here is that the interpolation function of the program calculates values for areas where data is not known as if data were known; it therefore erroneously extrapolates values from the valley across the mountain (as if the mountains did not exist) and into the desert.

(3) The SYMAP barriers procedure is discussed in detail in Volume Two, Report L; the instructions for coding the D-BARRIERS package are contained in Volume Two, Report K, Section 2.

(4) Maps were requested showing the
Calculated Annual Maximum,
Geometric Mean,
Measured Maxima
Maximum For Each Year (12 values, when available),
0.1 Percentile, and
1 Percentile.

This request was made by Henry Burke and Dave Weig of the criteria and standards development program of NAPCA.

(5) See Volume Two, Report L for a discussion of the interpolation algorithm used in SYMAP; also, see Volume Two, Report D for a discussion of the problems of extrapolation to the periphery of the study area in the Kansas City Region study.

(6) Figure I-9 is the largest map produced as a part of the demonstration grant mapping studies --52" wide. This size map is expensive, requires the splicing together of 4 sections or panels, and does not retain detail when photo offset for printing on an 8 1/2" x 11" page.

(7) Even the desert monitoring stations were located in towns; therefore a high value can easily be the result of man-made sources rather than natural (desert) background dust concentrations.

(8) See Volume Two, Report F (Connecticut Study) and Report H (Puget Sound Region Study) for discussions of difference maps and illustrations of increase and decrease shown separately.

(9) See Volume Two, Report D, Kansas City Region Study

(10) See Volume Two, Report L, SYMAP Interpolation Characteristics

(11) When interpolation crosses two barriers the result is the same as no barrier at all; therefore, when one begins to divide a study area with several barriers, the result is overlap and confusion. Another minor drawback of barriers is the size limitation of 50 vertices; when making a very large map that demands detail, one may exhaust storage for vertices and therefore have to generalize the presentation--changes can be made in the storage size in the program if necessary.

(12) An example of pollutants in combination is contained in the Kansas City report (Volume Two, Report D). A single map was made showing areas where air quality standards were exceeded for one, two and three different air pollutants.

APPENDIX

COMPUTER GRAPHICS

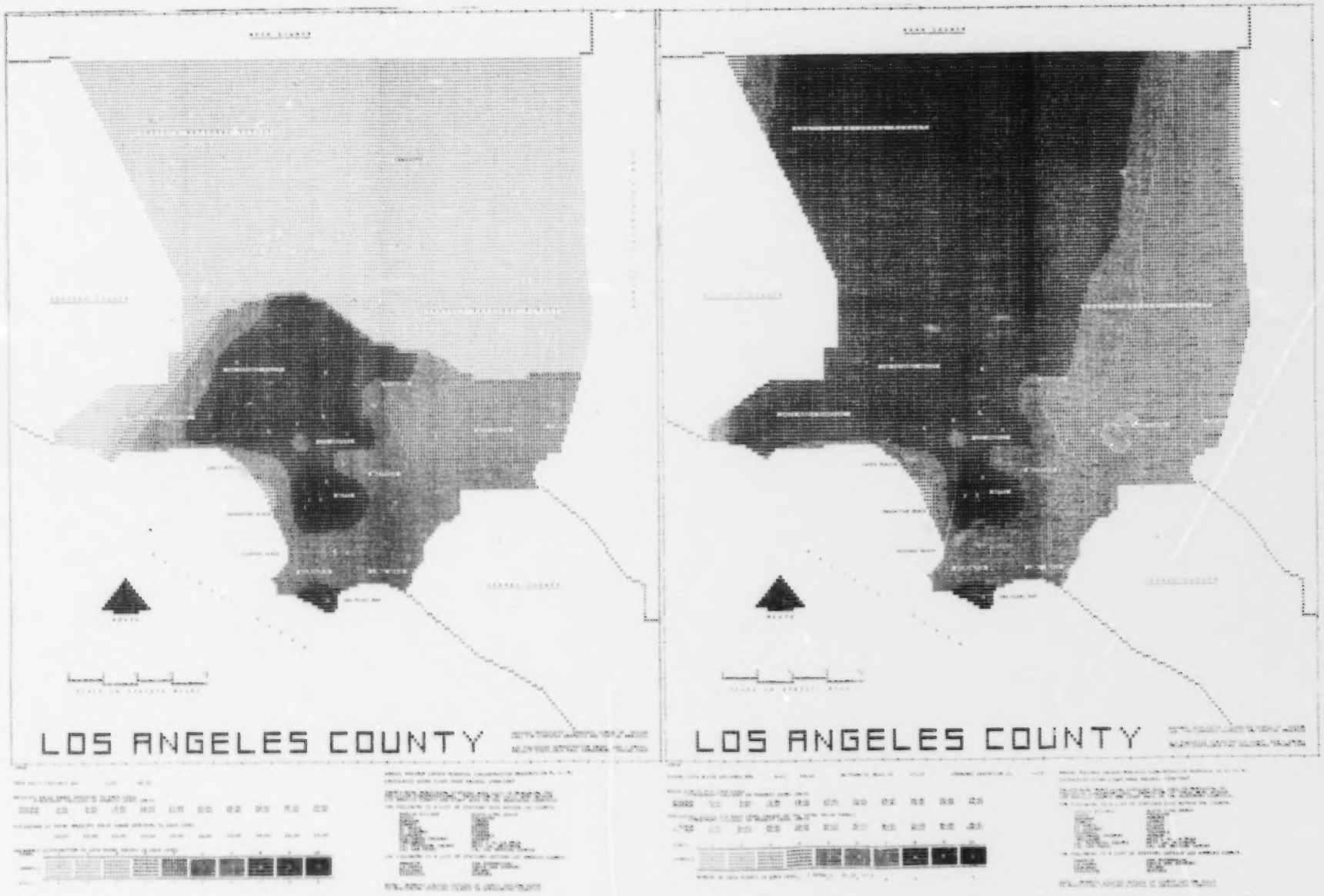


FIGURE I-1

LOS ANGELES COUNTY STUDY
Maximum Carbon Monoxide Concentration
Calculated Using 8-hour Values 1956-1967
a. Best Use of Barriers and Mountain Background Points
b. Measured Data Points Only

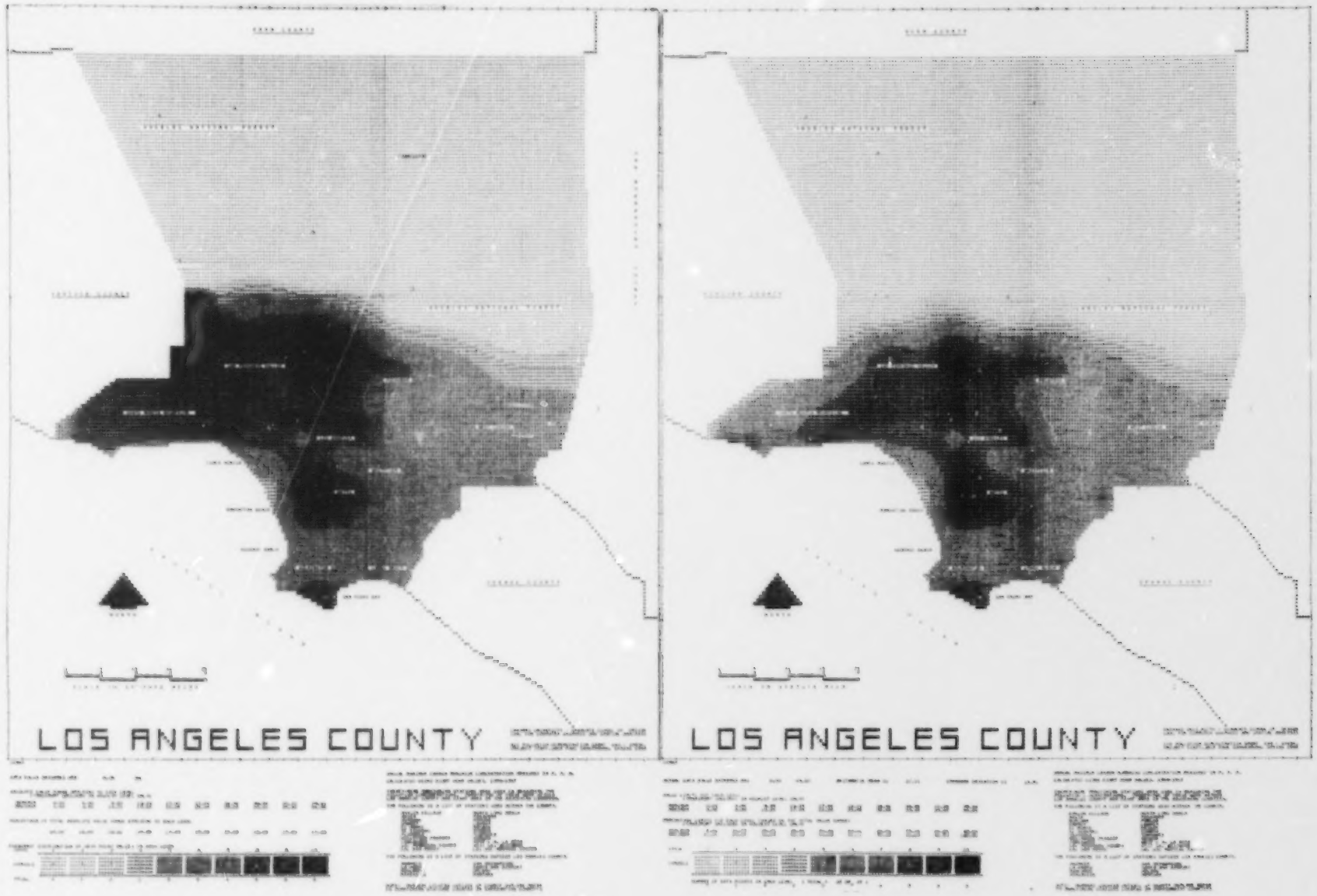


FIGURE I-2

LOS ANGELES COUNTY STUDY
Maximum Carbon Monoxide Concentration
Calculated Using 8-hour Values 1956-1967
Use of Mountain Background Points and Barrier
a. 2 Full-strenth Barriers and 5 Mountain Points
b. 8 Mountain Points

Details of illustrations in this document may be better studied on microfiche

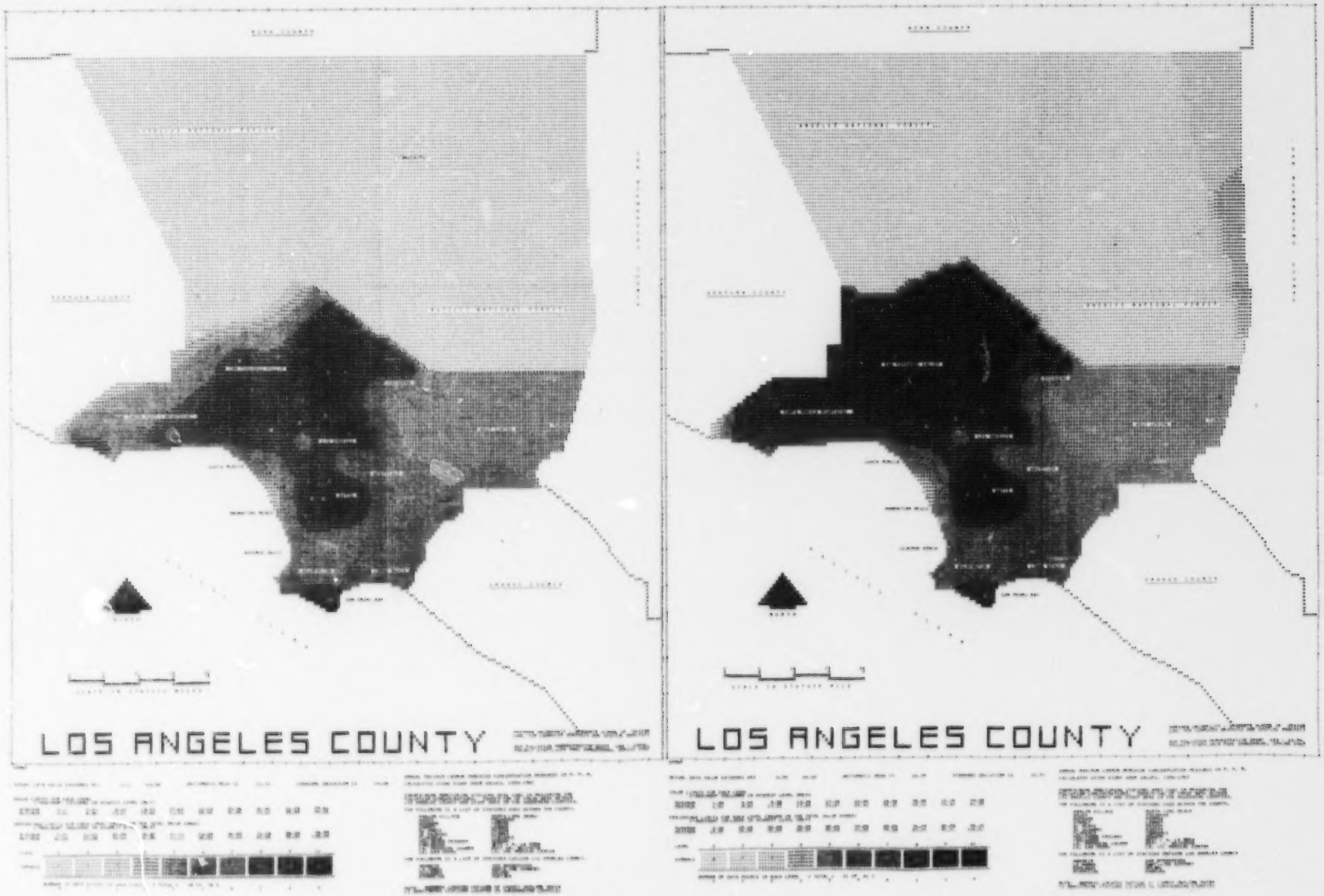


FIGURE I-3

LOS ANGELES COUNTY STUDY
Maximum Carbon Monoxide Concentration
Calculated Using 8-hour Values 1956-1967
a. Half-strength Barrier on Left; Full-strength on Right
b. Full-strength Barrier; Erroneous Influx from East

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FIGURE I-4

LOS ANGELES COUNTY STUDY
Maximum Carbon Monoxide Concentration
Calculated Using 8-hour Values 1956-1967
a. 2 Full-strength Barriers
b. Modeling Flow through Mountain Pass

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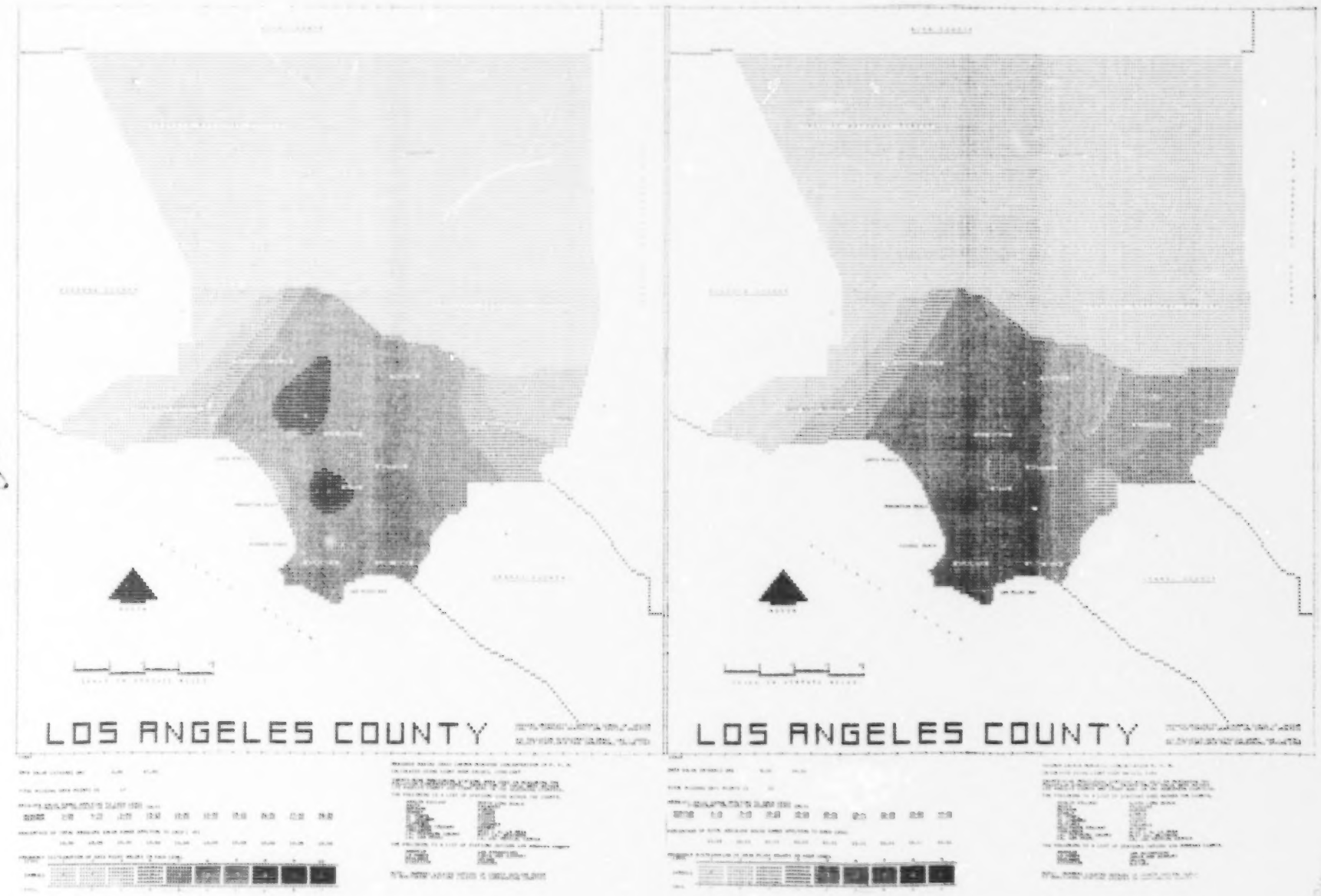

FIGURE I-5

LOS ANGELES COUNTY STUDY
Maximum Carbon Monoxide Concentration
Calculated Using 8-hour Values
a. 1956-1967 b. 1958

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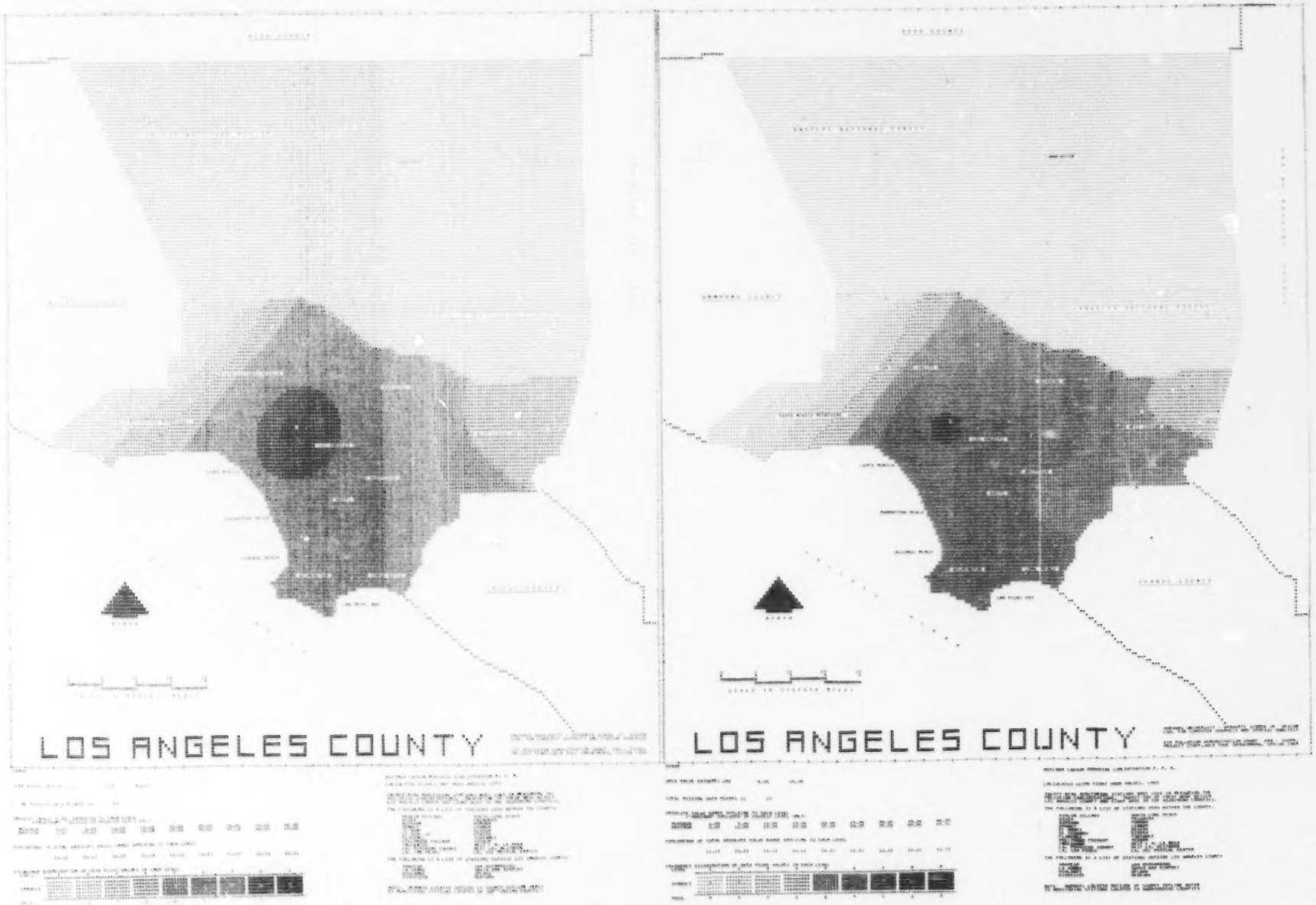

FIGURE I-6

LOS ANGELES COUNTY STUDY
Maximum Carbon Monoxide Concentration
Calculated Using 8-hour Values
a. 1959 b. 1960

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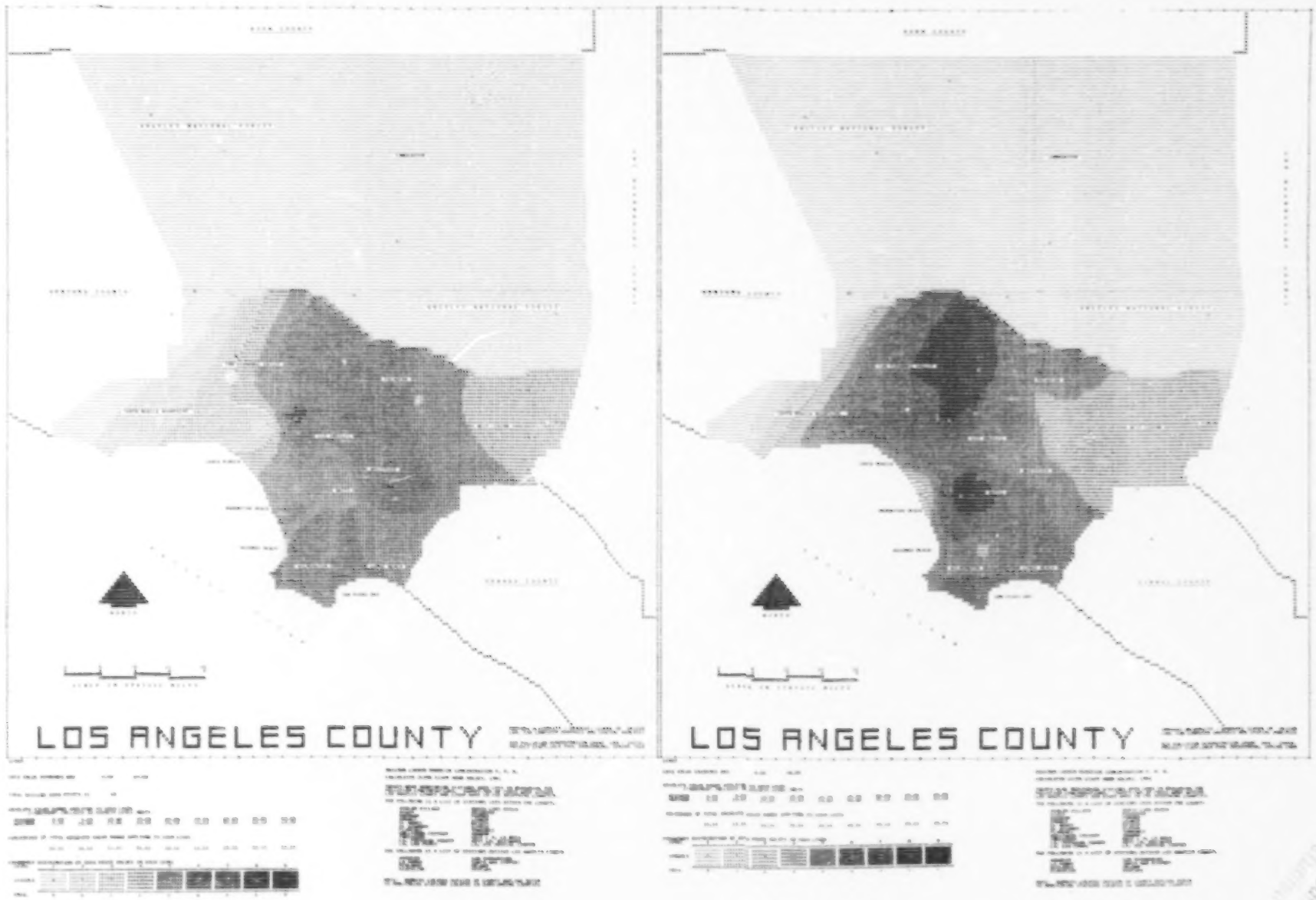

FIGURE I-7

LOS ANGELES COUNTY STUDY
Maximum Carbon Monoxide Concentration
Calculated Using 8-hour Values
a. 1961 b. 1962

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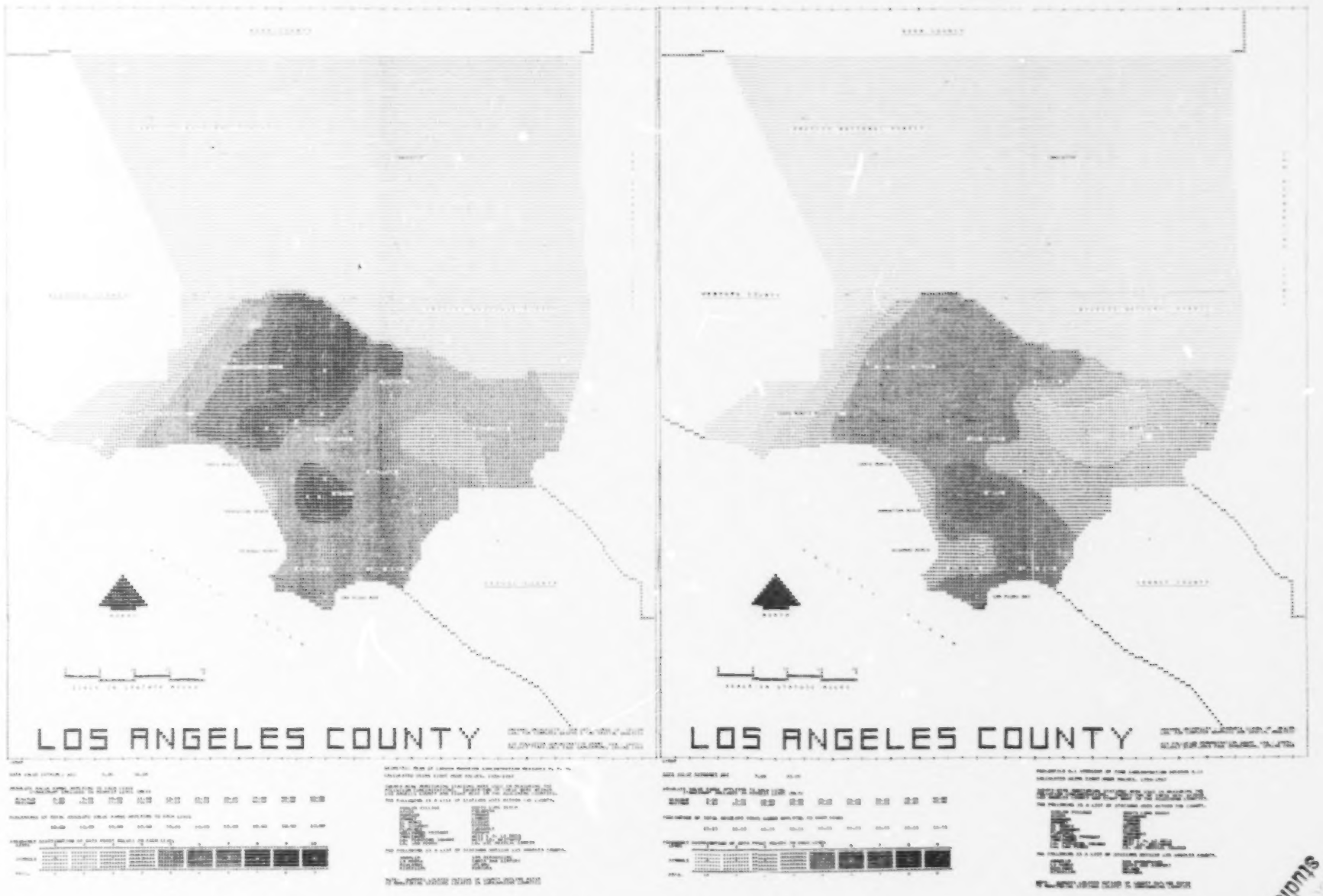

FIGURE I-8

LOS ANGELES COUNTY STUDY
Carbon Monoxide Concentration
Calculated Using 8-hour Values 1956-1967
a. Geometric Mean
b. Percent of Time Concentration Exceeds 0.1 p.p.m.

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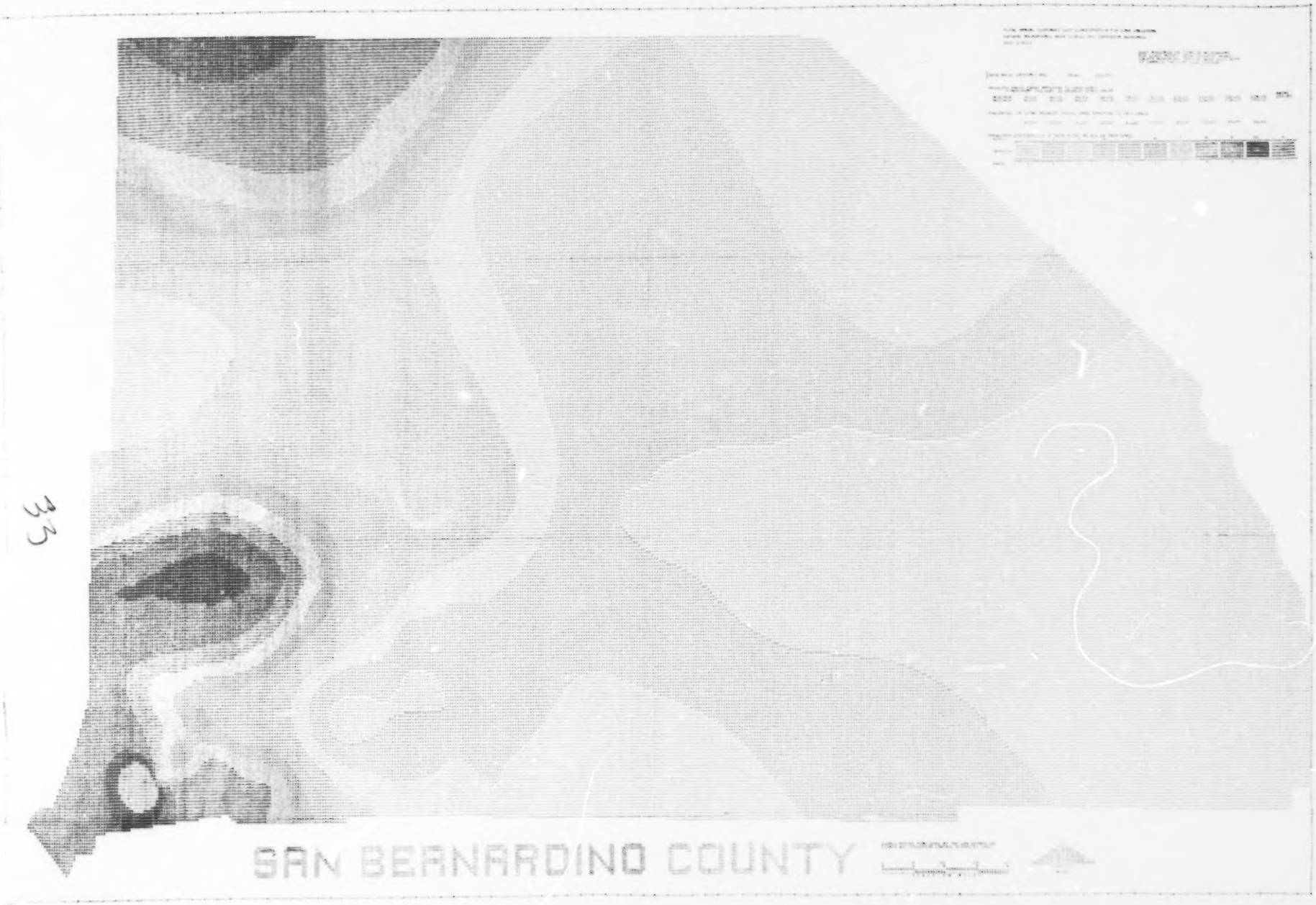

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FIGURE I-9

SAN BERNARDINO COUNTY STUDY
Total Annual Suspended Dust Concentration
1966

FIGURE I-10

SAN BERNARDINO COUNTY STUDY
Total Annual Suspended Dust Concentration
a. 1966 b. 1967
c. Absolute Increase, 1966 to 1967

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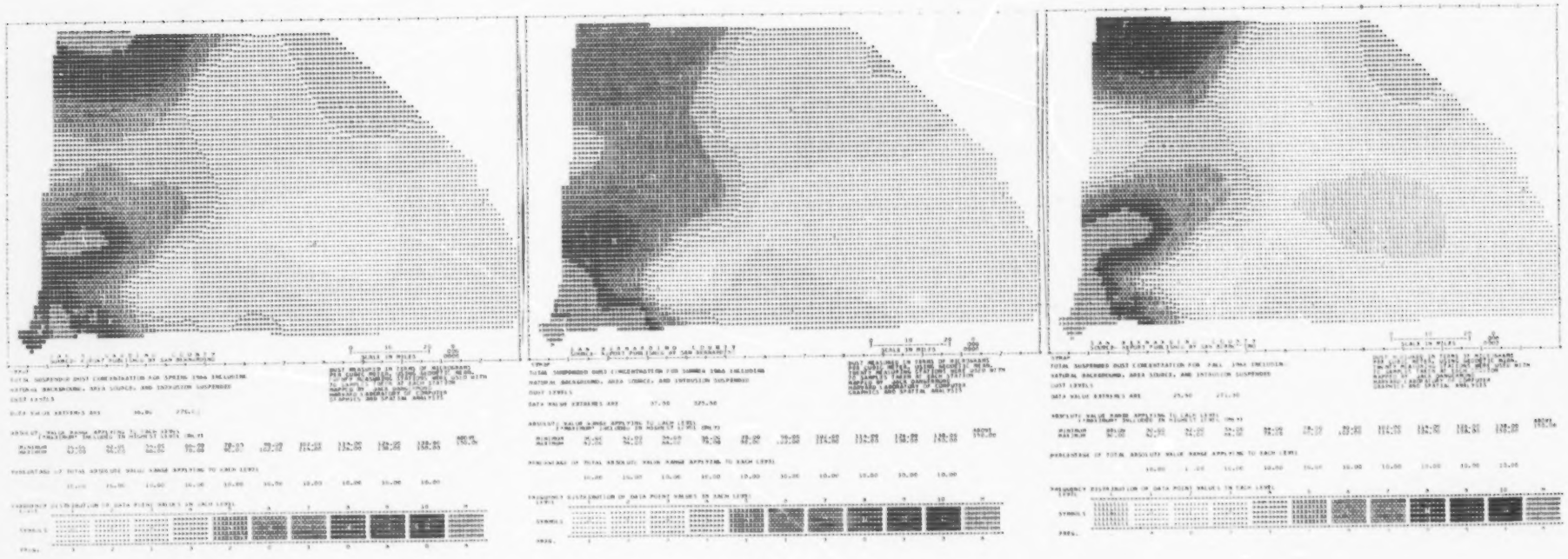

FIGURE I-11

SAN BERNARDINO COUNTY STUDY
Total Annual Suspended Dust Concentration
a. Spring b. Spring c. Fall

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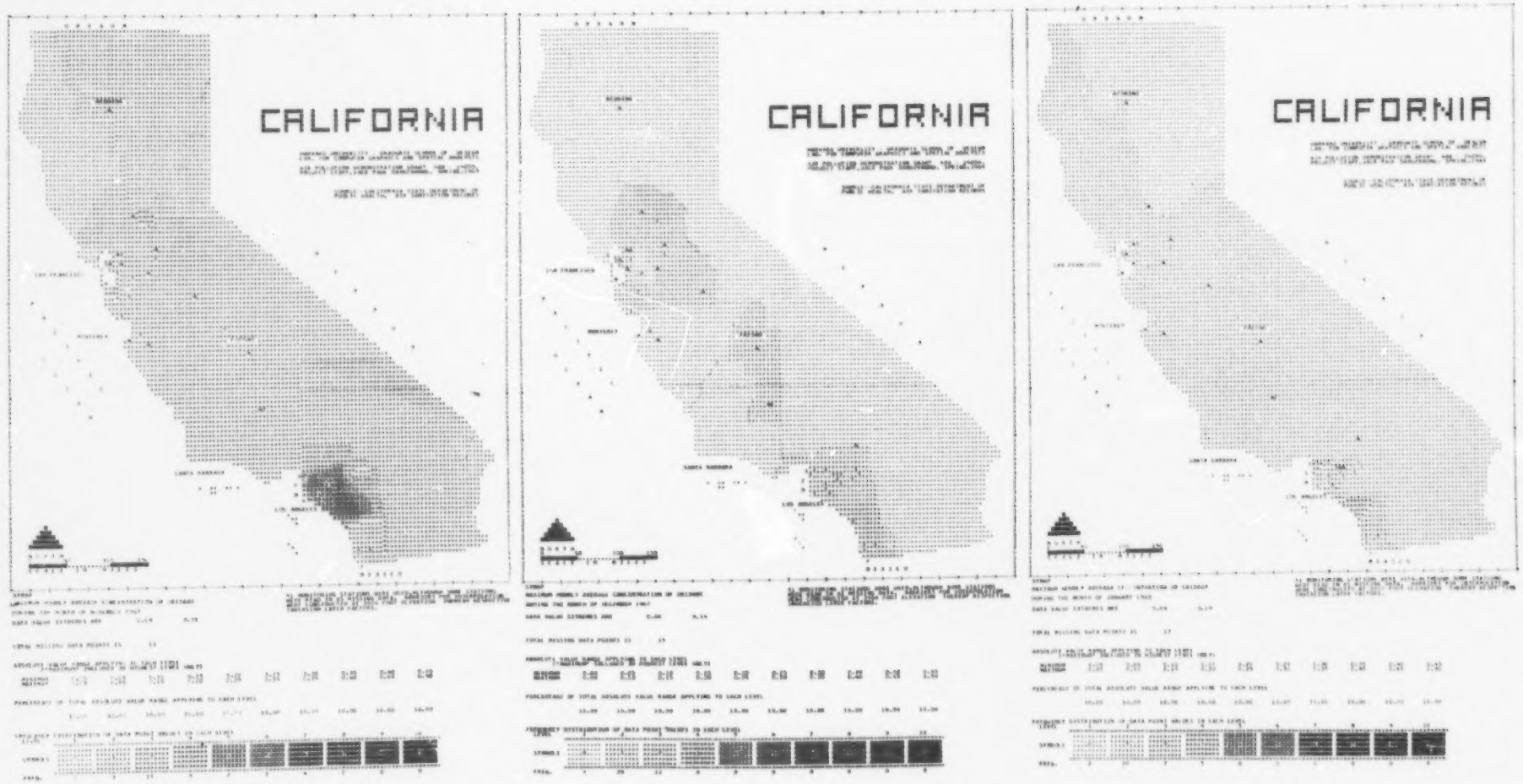

FIGURE I-12

CALIFORNIA STUDY
Maximum Hourly Average Concentration of Oxidant
a. November 1967 b. December 1967 c. January 1968

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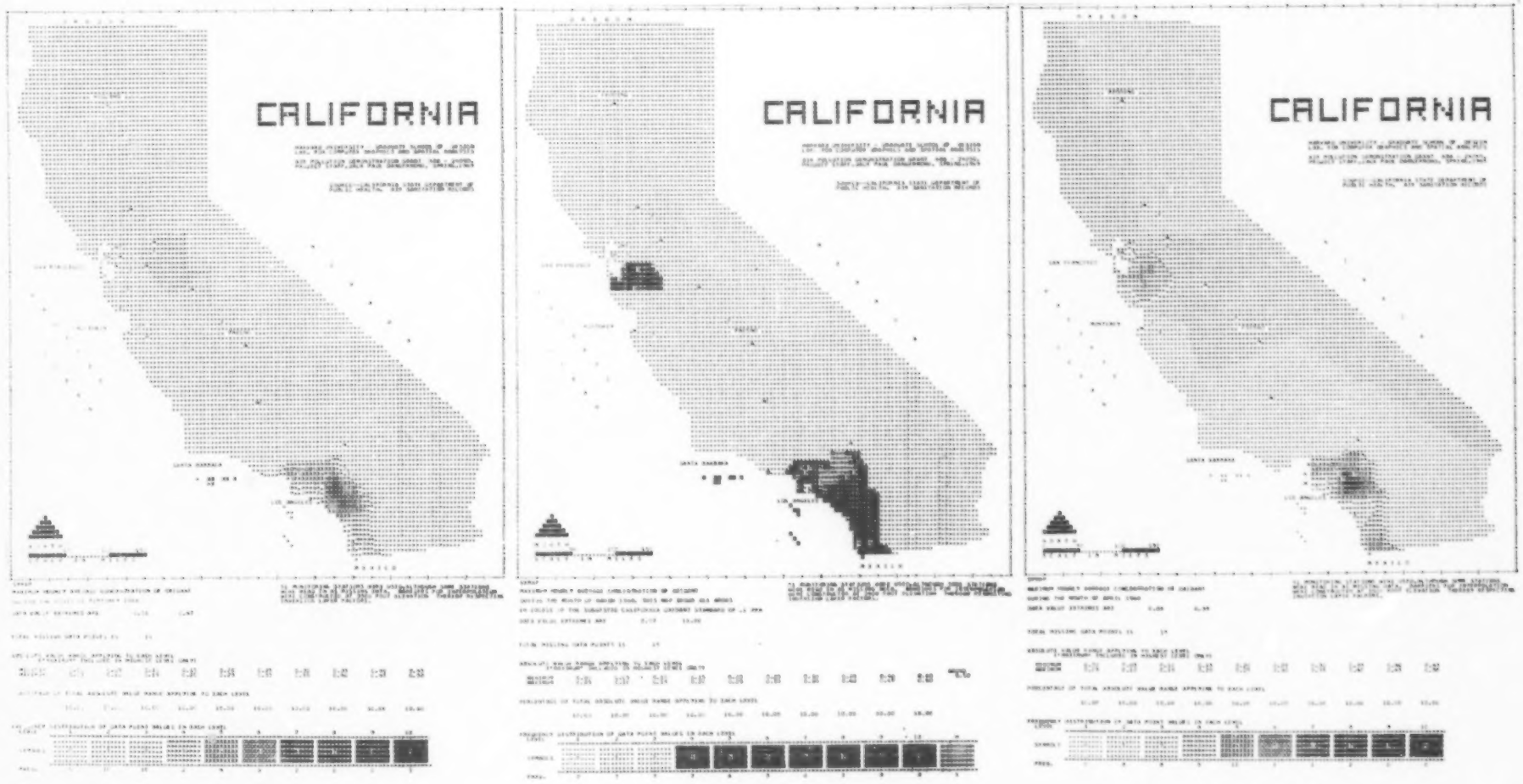

FIGURE I-13

CALIFORNIA STUDY
Maximum Hourly Average Concentration of Oxidant
a. February 1968 b. March 1968 c. April 1968

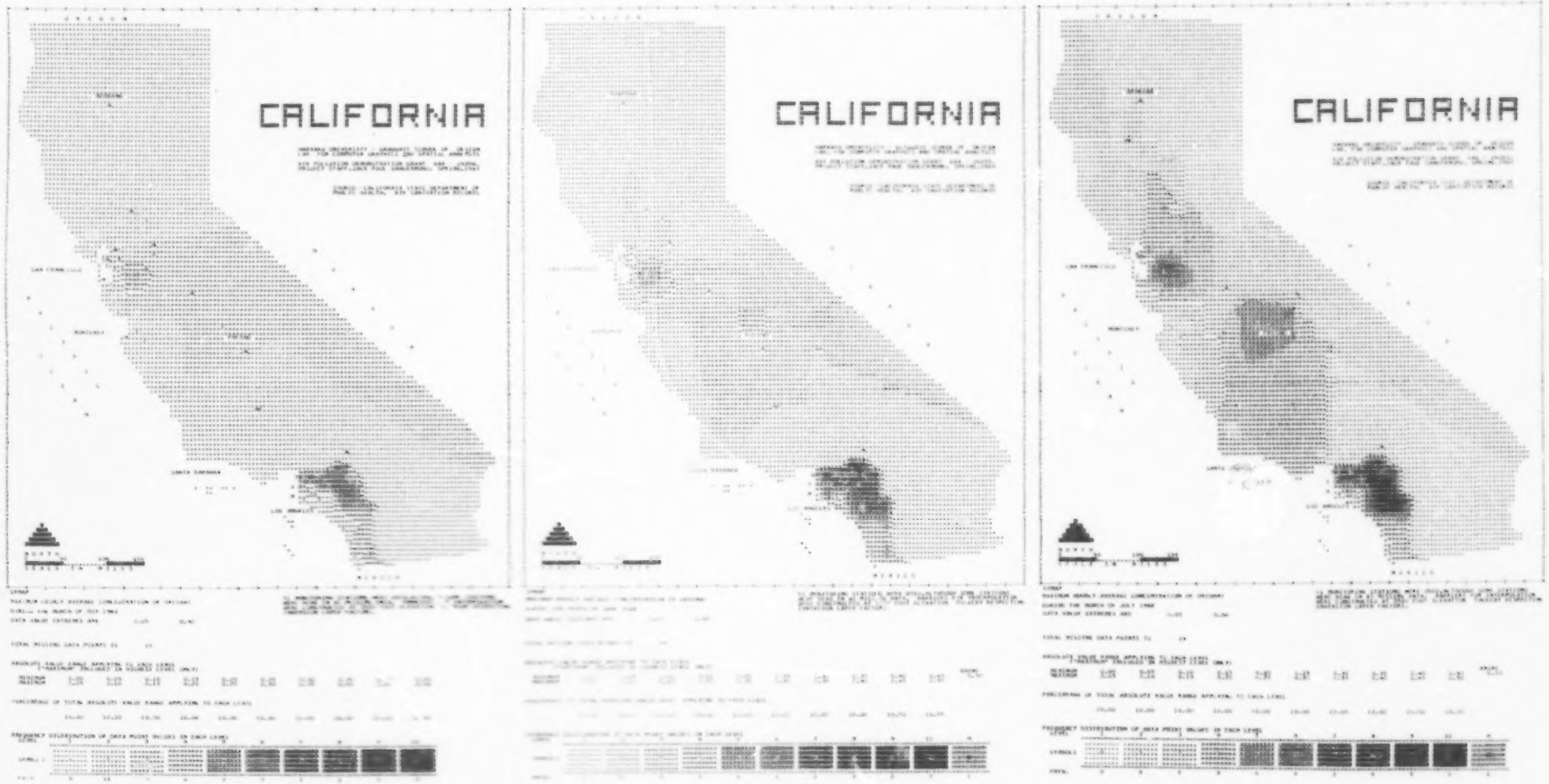

FIGURE I-14

CALIFORNIA STUDY
Maximum Hourly Average Concentration of Oxidant
a. May 1968 b. June 1968 c. July 1968

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